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SITE SELECTION FOR MANNED MARS LANDINGS: A GEOLOGICAL PERSPECTIVE

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ABSTRACT

Issues relating to the selection of initial landing sites for manned Mars missions are discussed from a geological viewpoint. The two prime objectives for initial manned exploration should be the youngest, unambiguous lava flows (to tie down the late end of the cratering history curve for Mars) and old highland crust, which is best sampled and studied through the use of large impact basins as natural, planetary drill-holes. Exploration of these two sites will provide data on martian chronology, volcanism, impact processes and gross chemical structure that will enable a first-order global synthesis through integration of these results with the global remote-sensing data already in hand from Viking and that to be provided by the Mars Observer Mission.

INTRODUCTION

A system to deliver men to the surface of another planet implies scientific capabilities many times greater than that of an automated, unmanned exploration spacecraft (see Taylor, 1975). Although site selection for the initial manned landings on Mars will be guided by many complex factors, the geological perspective is the purpose of this contribution. Other scientific disciplines, such as geophysics, may be interested in different sites. For the purpose of this discussion, I will concentrate on potential landing sites that will fundamentally contribute to deriving a detailed knowledge of martian geologic history. This involves selecting landing sites that span the vast ranges of time and processes that we observe on the surface of Mars.

A GEOLOGIC RATIONALE FOR MARTIAN LANDING SITE SELECTION

Although numerous studies are conducted during mannned missions, from a geological point of view, we are interested primarily in: 1) absolute ages of regional stratigraphic units; and 2) the composition, lithology, and possible paleontology chemistry, of rocks that make up the martian surface. Geological mapping based on returned photographs (e.g. Scott and Carr, 1978) has shown that Mars is a complex, heterogeneous planet, with regional geologic units that span the range from heavilycratered terrain (representing the oldest units) to very sparsely-cratered lava flows (representing some of the youngest units).

In selecting landing sites to address the global history of Mars, a general strategy might be based on establishing two end points for martian geologic history. First, we would like to know the absolute age of the <u>youngest</u> martian lava flows. This would answer the questions: When did martian volcanism cease? By calibrating the lower end of the planet-wide crater-frequency curve, the absolute age of most martian geologic units could be derived. Moreover, sampling lava flows not only gives us direct information concerning the composition of martian surface units, it also indirectly provides data on the probable chemical and petrologic nature of the martian mantle. Second, a landing site to sample and investigate the <u>oldest</u> martian geologic units would provide data at the opposite end of the age spectrum. This is best accomplished on Mars, as it is on the Moon, by sampling the rims of multi-ring basins, which are large impact craters that have excavated many kilometers into the crust of Mars. We therefore, have an opportunity not only to obtain samples of the ancient martian crust for age dating, chemistry and petrology, but also the potential to establish any vertical stratigraphy that may exist within the crust by reconstructing the basin impact target. Additionally, all martian basin landing sites appear to be partially embayed by numerous geologic units of diverse ages. Thus, a manned mission to one of these sites could not only provide data for early martian history, but also fill in gaps by sampling and dating some intermediate age units as well.

These two prime objectives, to investigate both the latest and earilest martian geologic units, will enable global extrapolations that should give us a fairly complete understanding of martian geologic history. The intermediate phases of martian history could be reconstructed by carefully integrating global photographic and remote-sensing compositonal data (to be provided by the MGCO mission), with the results of manned sample return and geologic exploration. However, detailed knowledge of martian geology will probably come only after many generations of surface exploration. Such a long range plan is beyond the scope of this paper; the following section will briefly describe some selected landing sites that will maximize the geologic return of brief series of manned missions and will give a broad knowledge of the geologic history of Mars and the processes that have shaped its surface.

SOME RECOMMENDED MARTIAN LANDING SITES

Mars is such a geologically diverse and complex planet (e.g. Mutch et. al., 1976; Carr, 1981), that to compile a list of geologically interesting landing sites to inventory all the processes that have operated during the planet's history would be an exercise in futility. Instead, this discussion will be confined to the two prime objectives listed above; some additional geologic "targets of opportunity" are presented, in addition to the prime sites, in Table 1.

Prime Objective 1 - The youngest martian lava flows

The Tharsis province of Mars possesses some of the most spectacular volcanoes observed in the solar system. It was recognized early in martian exploration that vast regions of this area contain few superposed impact craters, indicating a geologically-young age (Carr,1973; BVSP, 1981). Through detailed mapping and crater-counting of lava flows in the Tharsis region (Schaber et. al., 1978; Plescia and Saunders, 1979; Morris, in press), the youngest flows may be recognized (Fig. 1).

The smooth lava plains of the uppermost member of the Olympus Mons Formation (Scott and Tanaka, 1985) have the lowest cumulative crater density of all Tharsis flows (Number of craters $\geq$ 1 km diameter = 78 / 10^6 km^2; Morris, in press). Moreover, they are unambiguous lava flows, displaying flow lobes and pressure ridges (Fig. 2). A mission to this site would also have the opportunity to sample the basal scarp of Olympus Mons, the youngest shield volcano of the Tharsis province. The elevation of this site is between 2 and 3 km above the mean planetary level; if this elevation is too high for a spacecraft to obtain the necessary aerobraking capability, an alternate site exists at about 20^oN, 150^o (Table 1; Fig.2). This site is near the 0 km contour on the global topographic map. It consists of lava flows only slightly older than the previously mentioned Olympus flows ($N\geq$ 1 km ~ 100-200/ 10^6 km^2; Morris, in press). In addition to these young lavas, a carefully selected site at this locality could investigate both the distal margins of an ejecta-flow impact crater and the enigmatic aureole deposits of Olympus Mons (Fig. 2), for which diverse, and mostly unconvincing, origins have been proposed (see review in Carr,1981).

TABLE 1

GEOLOGICALLY-PRIORITIZED LIST OF LANDING SITES FOR MANNED MARTIAN EXPLORATION

SITE	OBJECTIVES	COMMENTS
1. Base of Olympus Mons[1]	a. youngest recognized martian lava flows	. elevation may be too high for sufficient aerobraking
	b. Olympus Mons flows; basal scarp on mountain	. lava flows are somewhat older than site 1
2. West of Auureole[1] (20^{o}N, 150^{o})	a. young lava flows	. lava flows are somewhat older than site 1
	b. aureole deposits	
	c. ejecta-flow impact crater	
3. Argyr basin[1] (47^{o}S, 30^{o})	a. basin massifs and ejecta	. wide diversity of features to investigate
	b. intercrater plains material	. geophysical net for Tharsis plateau
	c. eolian deposits and landforms	
4. Isidis Basis[1]	a. basin massifs and ejecta	. good for establishing global, geophysical net in conjunction with sites 1 and 2
	b. intercrater plains; basin-fill lavas	
	c. distal edges of Syrtis Major shield flows	
	d. small channels (fluvial drainage?)	
5. Chasma Boreale[2]	a. water ice and other polar volatiles	. address climatic problems
	b. layered terrain; nature and origin	
	c. northern plains material-periglacial processes and volcanic deposits	
6. Canyonlands[2]	a. stratigraphy in walls	. complex site, probably requiring many weeks of surface stay time
	b. debris and superposed deposits on canyon floor	
	c. processes of canyon formation	
7. Outwash channels[2]	a. fluvial (?) deposits	. ability to make long traverses (several 100 km) desirable
	b. origin and process	
8. Fretted terrain[2]	a. process and origin	. ability to make long traverses (several 100 km) desirable
	b. possible section into Martian crust	
9. Highland Patera[2]	a. highland volcanism (ash shields?)	. limited objectives site
10. Mangala Vallis region[2]	a. massive, unconsolidated deposits that straddle hemisphere boundary; origin under debate (ash flow?; polar deposits?)	. relevant to climatic questions or recent volcanism problems

NOTES:

1. Numbers along landing sites localities indicate relative priority, except that sites 1 and 2, and sites 3 and 4 are interchangeable, depending upon operational constraints.
2. No specific sites are given for these targets of opportunities, could be sites for follow-up missions after initial landings.

Figure 1. Young lava flows embaying the distal flanks of Olympus Mons (O). A site selected in a carefully chosen region (X) could sample both the young flows and portions of the Olympus Mons basal scarp. North at top; Viking subquad MC-9 NW.

Figure 2. Alternate site for young lava flows. Impact crater at top (C) displays ejecta flow morphology. Young lavas embay aureole deposit (A); this is a multi-objective site. North at top; Viking subquad MC-8 NE.

Either of these two sites would give us samples of the youngest unambiguous martian lava flow. As such, they would calibrate the planet-wide crater-frequency curve and enable us to extrapolate the results from this site to volcanic plains across the martian surface, which cover over 60% of the surface area of the planet (Greeley and Spudis, 1981).

Prime Objective 2 - The Ancient Martian Crust

Experience with Apollo lunar surface exploration has shown that investigations of multi-ring basins and their ejecta provide good strategies to reconstruct the composition and structure of planetary crusts. The cratered terrain hemisphere of Mars displays numerous basins, in preservation states ranging from near-pristine (e.g. Lowell; Wilhelms, 1973) to almost totally-obliterated (Schultz et. al., 1983). By investigating and sampling these basins, we can learn about the processes involved in basin formation, the age and composition of the martian highlands, and crustal stratigraphy and structure.

The Argyre basin in one of the best preserved, large (800 km diameter) martian multi-ring basins (Fig. 3; Table 1). A landing in this location would have several objectives. The prime sampling objective would be the basin massifs (Fig. 3). These mountains consist of both uplifted and rotated crustal blocks and /or basin ejecta, excavated from many kilometers depth (a model calculation suggests maximum depths of excavation for an Argyre-size basin at 40- 50km, extrapolated from the relation for lunar basins given in Spudis and Davis, 1985). Additionally, knobby-deposits (Fig.3) may well consist predominantly of primary basin ejecta, by analogy with similar deposits observed around the lunar Orientale basin (e.g. Head, 1974). Old plains material partially embays Argyre basin terrain; these units may consist of old volcanic flows that have resurfaced almost 50% of the martian cratered terrain hemisphere (Greeley and Spudis, 1981). Finally, a variety of eolian features, such as dune fields and etched terrain, occur within Argyre; both the morphology and process of eolian activity could be investigated at this site.

An alternate highland/basin site is the Isidis basin (Fig. 4; Table 1). This basin (1500 km diameter) may have been excavated to depths of 70 to 80 km into the martian crust. Objectives at this site consist of basin massifs as described above, basin-filling lavas, and the distal

Figure 3. The northwestern rim of the Argyre impact basin. Basin ejecta consists of rugged massifs and knobby terrain (K). Infilling plains (P) are probably lava flows. North at top; Viking subquad MC-26 NE.

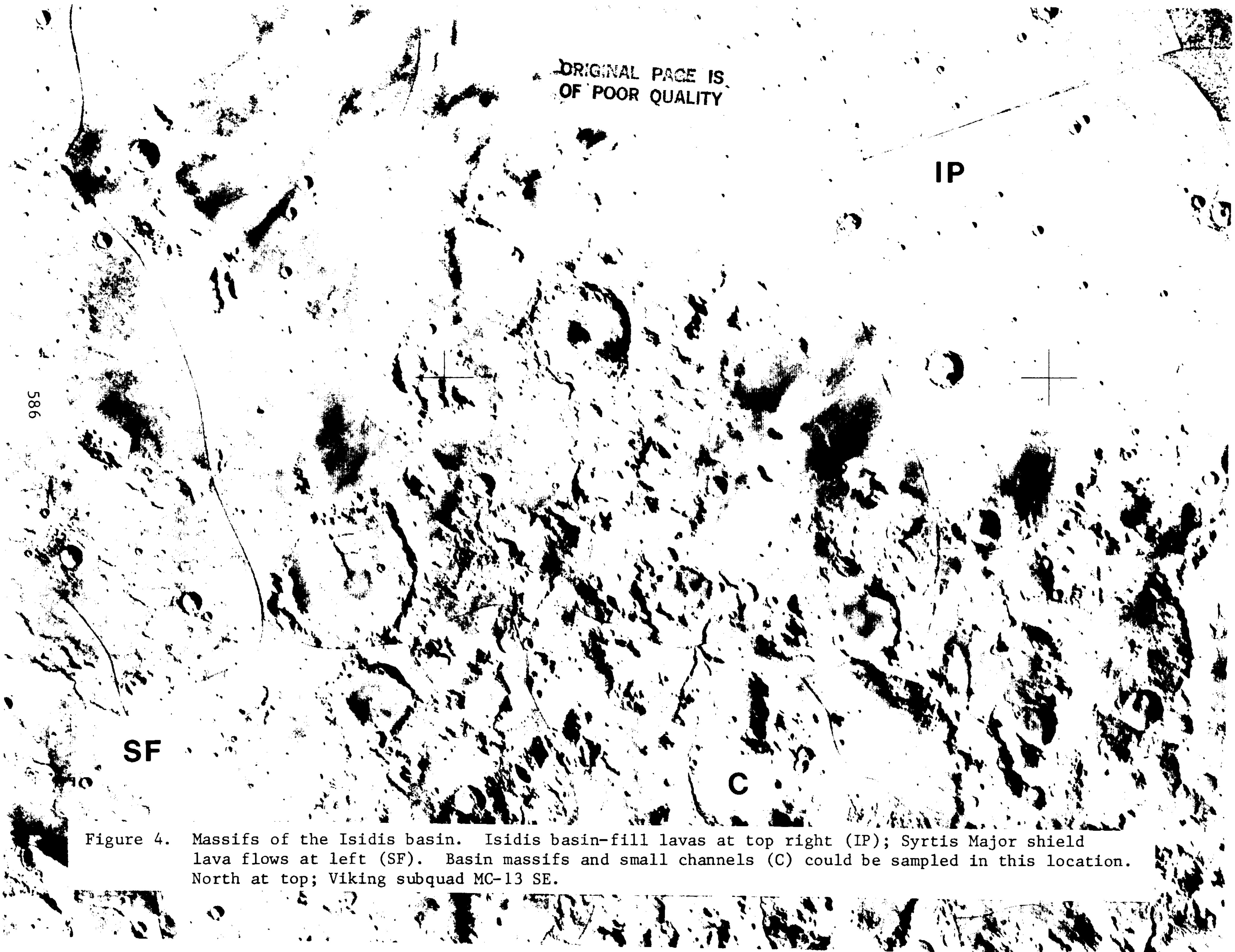

Figure 4. Massifs of the Isidis basin. Isidis basin-fill lavas at top right (IP); Syrtis Major shield lava flows at left (SF). Basin massifs and small channels (C) could be sampled in this location. North at top; Viking subquad MC-13 SE.

flows of the Syrtis Major shield volcano (Schaber, 1982). Additionally, some drainage channels occur within the rugged basin terrain (Fig. 4); another goal of this site would be to establish the nature of these channels, which may be of fluvial origin (Carr, 1981). An advantage of the Isidis site over the Argyre basin site described above is its near-antipodal location to the young volcanic sites described earlier; the placement of a geophysical station in both the Tharsis and Isidis regions might enable a determination of the existence and properties of a martian core.

Additional Sites of Geologic Interest

Six additional regions on Mars of geologic significance are listed in Table 1. As mentioned previously, Mars is such a complex planet, that a list hundreds of entries long could easily be given. In this tabulation, I have attempted to rank other targets only in terms of how they will help us address key issues in martian geologic history. After satisfying the two prime objectives, perhaps the most interesting site from both a geological and resources viewpoint is the north polar region (Table 1). Geologically, the polar layered deposits contain a record of alternating deposition and quiescence that is invaluable in terms of recent martian history. In terms of resources, the permanent polar cap is composed of water ice (Kieffer et. al., 1977). This resource is directly available at this site for life support at a permanent base and for propulsion uses.

The list presented in Table 1 is not meant to be definitive in any way. This is only an outline of site selection targets that will provide answers to several key questions regarding Mars. If the lunar experience is a guide, this initial exploration plan will probably raise many more questions than it answers.

CONCLUSIONS

The site selection strategy proposed here will address two key fundamental issues in martian geology: 1) the timing and composition of martian volcanism; and 2) the nature of the martian highland crust. Although detailed knowledge of martian geologic history will take decades of manned surface exploration, these initial manned landings will, at the very least, enable a formulation of the proper questions and provide a framework within which the evolution of Mars as a terrestrial planet can be understood.

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